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The Management of Chronic Kidney Disease Through Smart Wearables

Sibusisiwe Dube[1] John Mulopa[2], Xolani Moyo[3], Blessing Maninga[4], Tinashe Mbiririr[5], Sinokubekezela, Princess Dube[6]

[1]Lecturer, National University of Science and Technology, Department of Informatics and Analytics, Bulawayo, Zimbabwe

[2,3,4,5]Student. National University of Science and Technology, Department of Informatics and Analytics, Bulawayo, Zimbabwe

[6]Student. The University of Zambia, School of Engineering, Lusaka, Zambia

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ABSTRACT

Chronic Kidney Disease (CKD) is a condition that results from a malfunctioning kidney, and this disease is affecting a large population globally. Continuous management could delay progression to stage 4 and prevent complications. Currently, CKD management depends on physical clinic visits, which creates monitoring gaps, leading to reactive care. The emergence of smart wearables has provided the opportunity for continuous, remote monitoring. This paper presents findings showing that data from smart watches result in proactive CKD management. Quantitative data were collected from 50 CKD patients who voluntarily participated in the study.

The study findings demonstrated high feasibility of integrating smart wearables in CKD management, with a mean device adherence of 87% and successful data integration. Although (42%) indicated challenges in purchasing the smartwatch, their engagement with the technology was high, with 80% reporting increased knowledge about the CKD disease, increased adherence to medication due to reminders from the smart wearable, precise activity and rest metrics, and a reduction in missed medication doses.

These findings provide compelling proof that the integration of smart wearables into a structured management framework is feasible and acceptable to CKD patients. Smart wearables are affording patients a shift from intermittent to continuous monitoring of their condition, and promise an early detection of clinical deterioration in CKD patients. While challenges regarding validation, clinical integration, and equity remain, this approach paves the way for predictive, personalized care and management of CKD. Future work must focus on large-scale trials to validate clinical efficacy and hard endpoints.

Keywords: Smart Wearables, Watch, Chronic Kidney Disease, Patients, and Management.

INTRODUCTION

Chronic Kidney Disease (CKD) is a progressive condition that increases the risk of kidney function failure. This disease, CKD, has become a global health problem as it affects over 10% of the global population and remains a major cause of morbidity and mortality (Kovesdy, 2022: A Global Health Priority, 2024). For the approximately 850 million people affected by KKD, many fail to manage the CKD disease. Adding to this challenge is the fact that in many people, CKD is diagnosed very late because of its symptoms, which are not clearly visible, and make the periodic monitoring of CKD so challenging.

For example, traditional methods of managing CKD are very limited because they rely on infrequent clinical assessments, limiting the ability to detect early deterioration. Smart wearables are promising to improve the process of managing CKD because smart wearables are equipped with biosensors, wireless communication, and AI-driven analytics. These capabilities of smart wearables make them a valuable tool for better managing CKD.

The emergence of smart wearables provides CKD patients with an opportunity for continuous and remote monitoring of physiological parameters relevant to CKD progression, including blood pressure, hydration, activity levels, and cardiovascular indicators. With advances in sensor accuracy, connectivity, and predictive analytics, wearables are increasingly incorporated into chronic disease management pathways (Jafleh et al., 2024a).

User-friendly devices are capable of collecting vast amounts of continuous physiological and behavioral data, offering a powerful platform to revolutionize the management of chronic conditions, including CKD. (Wieringa et al., 2017a)F. For CKD patients who require frequent and multidimensional monitoring, these technologies may enhance early detection, support behavioral changes, and facilitate personalized care.

It is on this background that this paper presents a comprehensive report on the current applications, benefits, challenges, and future opportunities for integrating smart wearable technologies into CKD management. It was on this background that the main objective of this research is to investigate the current applications, benefits, challenges, and future opportunities for integrating smart wearable technologies into CKD management. This research sought to test the following hypotheses:

H_0: The management of CKD is not affected by the use of wearable devices.

H_1: Wearable devices improve the management of CKD.

Related Work

The integration of digital technologies into chronic disease management (CDM) has seen significant advancements, with research primarily evolving along four interconnected streams: mobile health (mHealth) applications, artificial intelligence (MI) for predictive diagnostics, wearable monitoring devices, and blockchain for data security. Existing work in each domain offers valuable insights, but also reveals critical gaps that an integrated system could address

Mobile Health and AI-Driven Predictive Applications

Research into mHealth applications for specific chronic conditions, such as CKD, demonstrates the potential of AI to enhance patient monitoring and clinical decision-making. For instance, Sun and Zhang (2024) developed a mobile application utilizing machine learning models, including Support Vector Machine (SVM) and XG-Boost, to predict anemia and dialysis needs in renal patients.

Their work highlights a focused approach to risk prediction using key clinical indicators, improving upon generalized health platforms like the Global Kidney Health Atlas (GKHA), which lacks personalization. Similarly, mHealth apps for chronic kidney disease (CKD) enable self-monitoring but often confuse users with complex biomarkers like creatinine.

While these applications successfully leverage AI for prediction, they are typically condition-specific and do not integrate continuous, real-time data streams from patients’ daily lives, limiting their proactive capabilities and holistic health view.

Machine Learning for Early Disease Detection

The application of advanced ML techniques for early prediction represents a robust area of study. Research, such as that by Kalluru et al. (2025), explores models like Convolutional Neural Networks (CNN), Cat-Boost, and hybrid approaches to predict and stage CKD.

These studies emphasize handling class imbalance with techniques like SMOTE and improving interpretability with Explainable AI (XAI). The focus is often on maximizing accuracy from static clinical datasets. However, a common limitation is the reliance on historical, episodic data rather than dynamic, continuous physiological inputs. This restricts the model's ability to provide real-time, adaptive risk assessments and early warnings for acute events, a necessity for effective chronic disease management.

Wearable Technology for Continuous Monitoring

Wearable devices have revolutionized continuous physiological monitoring across cardiology, endocrinology, respiratory health, and neurology. Comprehensive reviews, such as that by Jafleh et al. (2024b), detail the efficacy of devices like smartwatches for detecting atrial fibrillation, continuous glucose monitors (CGMs) for diabetes, and accelerometers for managing Parkinson’s disease.

These devices enable real-time data collection, promoting patient engagement and allowing for remote patient monitoring (RPM). Despite their benefits, challenges persist regarding data accuracy, sensor reliability during intense activity, user adherence, and significant data privacy concerns. Crucially, data from these wearables often reside in siloed applications, lacking secure, interoperable frameworks for aggregation and comprehensive analysis by healthcare providers

Blockchain for Secure Healthcare Data Management

To address security and interoperability issues, blockchain technology has been proposed for healthcare. Research by Saxena et al. (2025) conceptualizes a Hyperledger Fabric-based framework to create a tamperproof, decentralized ledger for patient data from wearables and AI analysis. This approach aims to ensure data integrity, patient privacy through permissioned access and seamless sharing across stakeholders. Other studies highlight blockchain's potential in supply chain security, smart contracts for automated insurance, and identity management.

However, many proposed blockchain integrations in healthcare remain theoretical or are in early stages of implementation. There is a noted gap in fully realized systems that effectively unify AI-driven analytics from wearables with the security and transparency of blockchain in a scalable, clinically deployed environment.

Synthesis and Identified Gap

Current research robustly addresses individual components of digital health: AI for prediction, wearables for sensing, and blockchain for security. However, these technologies are often investigated in isolation. The prevailing gap is a lack of a fully integrated, patient-centric framework that synergistically combines real-time data acquisition from multi-parameter wearables, advanced AI for continuous analysis and predictive alerting, and blockchain for ensuring the security, privacy, and integrity of the entire data lifecycle.

Our work builds upon these foundations by proposing and developing a cohesive system designed to overcome the limitations of siloed solutions, thereby advancing towards a more proactive, secure, and comprehensive model for chronic disease management.

METHODS AND DATA COLLECTION

This section details the research design, participant selection, intervention protocol, data collection methods, and analytical approach employed to evaluate the effectiveness and user acceptance of smart wearables for CKD management. A questionnaire was used to collect quantitative data, which included age, sex, BMI, CKD stage/e, their additional or other current chronic medical conditions, such as hypertension, diabetes, as well as the medication regimen. Fifty patients who voluntarily participated in this study were recruited from 5 clinics in an urban area of a developing country.

The study purposively sought patients who were on stage 3 or 4 of CKD, aged between 18 and 75 years. The participating CKD patients owned a smartphone that would be compatible with the Samsung watches donated by a non-profit organization (NGO). Furthermore, the recruited research subjects had a basic digital literacy to enable them to operate the functions of the installed mobile application.

The 50 CKD patients used donated smart watches to manage their CKD condition. Smart watches helped the CKD patients to record (1) daily step count, distance, and active minutes, (2) total sleep time, sleep stages, and wake-ups, (3) testing and active heart rate. The 50 patients' smartphones were installed with a mobile application for (1) displaying visualized metrics captured by the wearable, (2) setting patients' personalized goals, (3) providing reminders to take medication, and (4) recommendations for CKD-specific nutrition and lifestyle advice.

RESULTS AND DISCUSSION

This section presents the week-long recordings of each participating CKD patient who participated in the survey.

Demography

Many CKD patients participating in this research were in the age range of 51-60 years, while the 21–30-year age group was less represented, as depicted in Figure 1,1.

Figure1.1: Age-based CKD distribution

Literature concurs that CKD is more common among the 40-60 years age group (Johansen et al., 2024), (Johansen et al., 2024)The findings of the study also show a difference in the CKD condition among males and females. Figure 1.2 shows that males are more susceptible to CKD than females. Literature provides evidence to show that more men than women suffer from CKD (Melsom et al., 2022; Duan et al., 2019).

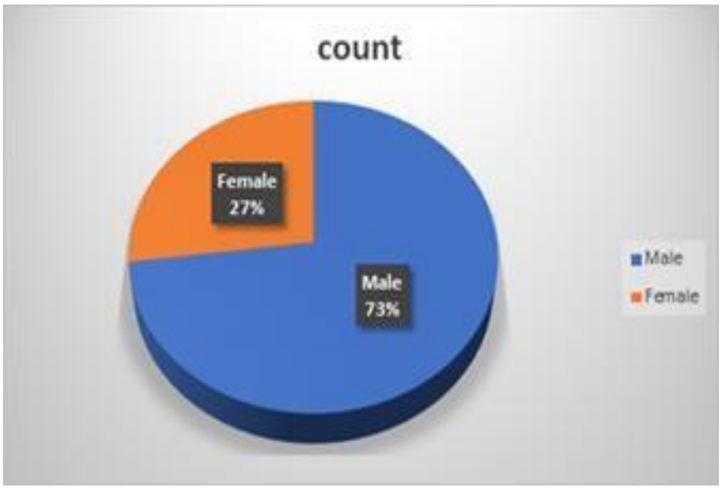

Figure1.2: Gender based CKD distribution

Details of the Disease

Many research participants indicated that they are on stage 4 of the CKD condition, while 38% are on stage 3, as indicated in Figure 1.3.

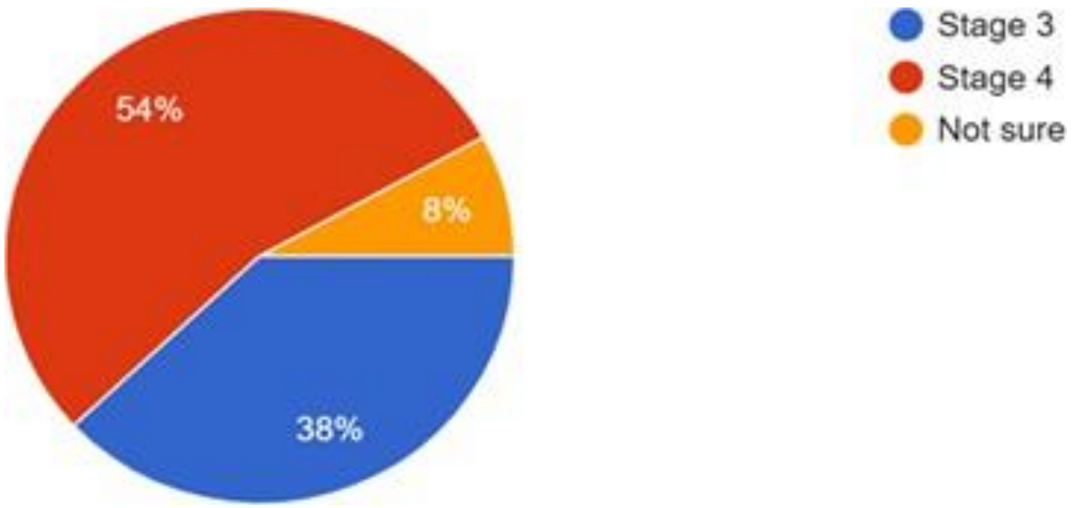

Figure1.3: Participating Patients' CKD stage

Literature confirms that the failure to manage CKD accelerates the progression from stage G3 to stage G4 of the CKD condition (Melsom et al., 2022). These findings also show that many of those affected by CKD are battling with other conditions such as diabetes and hypertension. Figure 1.4 depicts the distribution of diabetes and hypertension among the research participants who are already suffering from CKD.

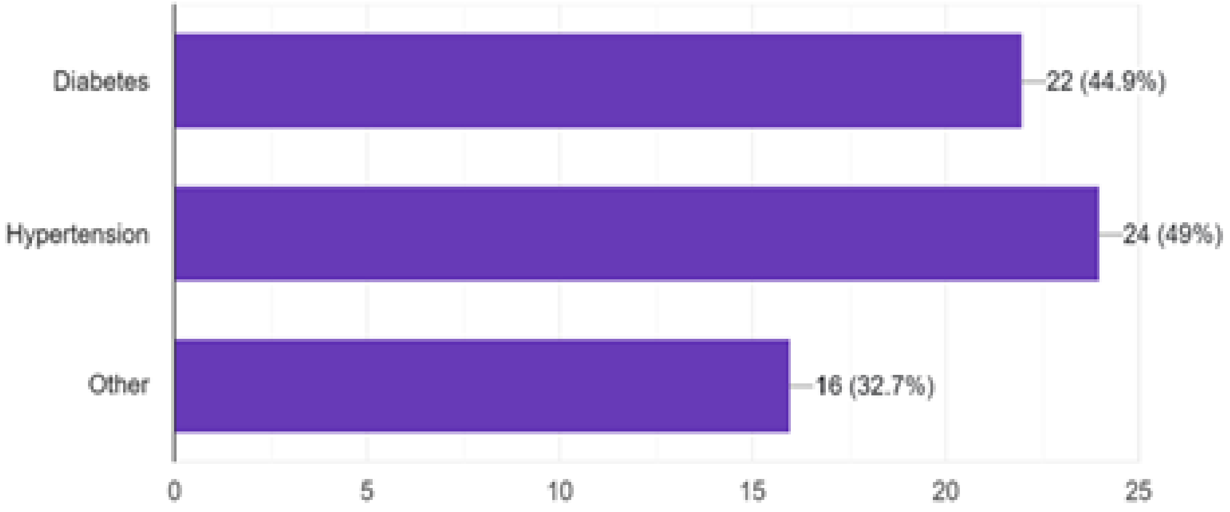

Figure1.4: Other conditions for CKD patients

The self-reported results in Figure 4 show that many CKD patients (49%) have a hypertension condition, while (45%) have diabetes. Literature has evidence of the close association between CKD and other chronic diseases such as diabetes and hypertension (Melsom et al., 2022; Duan et al., 2019). For example, Hsu & Hsu (2016, p. 1899) acknowledge that "In the general population, it is associated with diabetes, obesity, prediabetes, hypertension, and subsequent GFR loss…".

Activity Steps and Sleep Time

The CKD patients who participated in this study were asked to keep a log of both their daily steps and the hours they spent sleeping as recorded in the smart watch. The average steps count was 5000 steps while the majority indicated that their sleeping time averages 8 hours (23%), followed by 6 hours (21%), 9 hours (18%), 7 hours (15%), 5 hours (13%) and the least 4 hours (10%), all which are illustrated in Figure 1.5.

Figure1.5: Sleep Metrics for CKD patients

Interestingly, many respondents (62%) indicated that they were regular in taking their medicines, while (38%) confirmed that they were not consistent and needed reminders.

Gender-based Daily Physical Activity

Table 1.1 compares the average Daily physical activity between two groups based on Gender (coded as 1.0 for male and 2.0 for female). Group 1.0, male (N=26), has a slightly higher average level of daily physical activity (Mean = 4.423) than Group 2.0, female (N=24) (Mean = 4.167). On average, the male group reports slightly higher physical activity than the female group. The difference between the two averages is 0.256 points. The standard deviations are very close (0.902 vs. 0.868), indicating that the amount of "spread" or variability in physical activity levels is similar for both genders.

Table1.1. T-Gender-based CKD Patients Active time

	Gender	N	Mean	Std Deviation	Std Error Mean
Daily physical activity	1.0	26	4.423	0.9021	0.1769
	2.0	24	4.167	0.8681	0.1772

Table 1.2 presents the results of whether the difference in means observed in the Group Statistics in Table 1.1 (4.423 vs. 4.167) is statistically significant.

Table1.1. 2-Independent Sample test for CKD Patients' Physical Activity

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Daily physical activity	Equal variances assumed	.173	.680	1.022	48	.312	.2564	.2508	-.2479	.7607
	Equal variances			1.024	47.910	.311	.2564	.2504	-.2471	.7599

	not assumed									

The results depicted in Table 1.2 of t(48) = 1.022,p =.312 show that there is no statistically significant difference in daily physical activity between Gender 1.0 and Gender 2.0.

It is clear from Table 1.2 that Group 1.0 (males) reported slightly higher activity (4.42 vs. 4.17); however, this difference is so small that it could easily have occurred by chance, and therefore it cannot be concluded that gender differences exist in physical activity levels.

Rather, these results demonstrate that there was no significant difference in daily physical activity scores between Group 1 (M = 4.42, SD = 0.90) and Group 2 (M = 4.17, SD = 0.87); t(48) = 1.02, p = .312.

Gender-based Sleep Time

Table 1.3 presents test results of the comparison that compares the average total sleep time between two groups based on gender (coded as 1.0, male, averaging 6.885 hours, and 2.0, female, averaging 6.500 hours). These results depict male patients as sleeping approximately 0.385 hours (or about 23 minutes) longer than their female counterparts.

The male patients' sleep times vary by about 1.61 hours (about 1 hour and 37 minutes) from the mean, while the female patients' sleep times vary by about 1.69 hours (about 1 hour and 41 minutes) from the mean. It is evident in Table 1.3 that the standard deviations are very similar, which means that the amount of variability in sleep patterns is approximately the same for both genders. The result also suggests that the spread of data is comparable.

Table1.3.2Gender-Based CKD Patients' Sleep Time

Variable	Gender	N	Mean	Std. Deviation	Std. Error Mean
Total Sleep Time	Male (1.0)	26	6.885	1.6082	0.3154
	Female (2.0)	24	6.500	1.6940	0.3458

Although Table 1.3 showed that male CKD patients slept an average of 23 minutes longer than the female CKD patients (6.89 hrs vs. 6.50 hrs), Table 1.4 shows that this difference is not large enough to be considered significant.

Based on these results, it cannot be concluded that the genders differ in their total sleep time in the broader population, which confirms that there is no statistically significant difference in total sleep time between males and females as indicated in the formular, t (48) = 0.824,p = .414. in conclusion, there was significant difference in total sleep time between Group 1 (M = 6.89, SD = 1.61) and Group 2 (M = 6.50, SD = 1.69); t(48) = 0.82, p = .414.

Table1.4. Independent Sample Test for CKD Patients' Sleep Time

	Levene's Test for Equality of Variances		t-test for Equality of Means						
								95% Confidence Interval of the Difference	
	F	Sig.	t	df	Sig. (2tailed)	Mean Difference	Std. Error Difference	Lower	Upper

Total sleep time	Equal variances assumed	.440	.510	.824	48	.414	.3846	.4670	-.5544	1.3236
	Equal variances not assumed			.822	47.159	.415	.3846	.4680	-.5568	1.3260

Paired Test of CKD Stage vs. Other Chronic Diseases

Table 1.5 depicts results that patients with early-stage CKD (around Stage 1.7) tend to have a similar number of additional chronic conditions (around 1.8). This could imply that even in early kidney disease, patients are already dealing with multiple health issues.

Table 1.5. Paired Samples Statistics of CKD stage against other chronic conditions

		Mean	N	Std. Deviation	Std. Error Mean
	CDK stage	1.720	50	.6074	.0859
Pair 1	Other chronic conditions that you are managing	1.760	50	.8221	.1163

Table 1.6 shows a very weak negative correlation (r = −.056), between the CKD stage and the existence of other chronic diseases like diabetes, and this correlation is not statistically significant (p = .701.

While the average levels of these two variables are similar for the group, there is no consistent pattern linking them at the individual level. A patient with a higher CKD stage (e.g., Stage 3) is just as likely to have few other conditions as they are to have many. The two factors appear to operate independently in this sample.

Table1.6 Correlation Between CKD Stage and Other Chronic Conditions

Variables	N	Correlation (r)	Sig. (p-value)
CKD Stage & Other Chronic Conditions Being Managed	50	-0.056	0.701

Patients' Perceptions about Wearable Devices

After a week of managing CKD using the smart watch, the research participants were asked to provide feedback regarding the perceived ease of use and the perceived usefulness of the technology in managing their condition. The findings show that the majority (85.7%) appreciated the value of smart watches in managing CKD, while only (14.3%) did not find any added value in using smart watches.

Commenting on the perceived ease of use, the majority indicated that they had challenges (69%) and just a few (31%) had no issues in managing CKD using a smart watch, Despite the challenges faced in using the smart wearables, the research participants (44%) are willing to continue using the wearable hence their desire to purchase the device.

The motivating factors for purchasing the smart wearable included the technology's ability to send reminders (86%), followed by Doctors' appointment alerts (74%), while a few were interested in goal setting (38%), as illustrated in Figure 6.

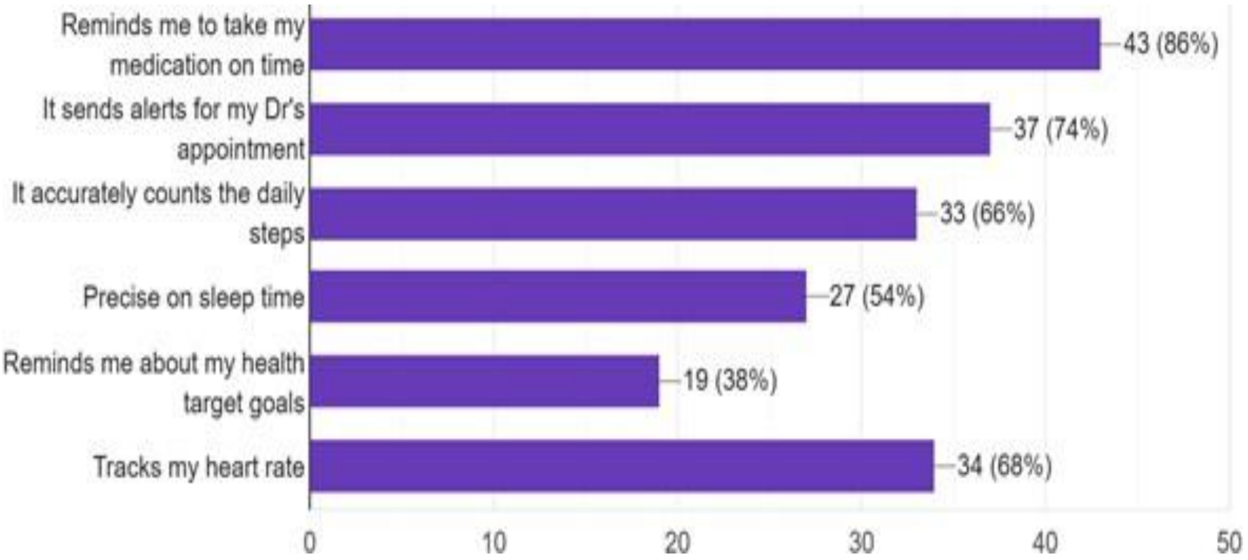

Figure1.6: Usefulness of smart wearables in CKD management

The findings depicted in Figure 6 are supported by literature, which suggests that wearable devices are useful for managing CKD through enabling the patients to track their exercise, monitor diet, remote consultations, and patient education (Wieringa et al., 2017). Some of the reasons for anti-wearables included high cost (67%), maintenance (27%), and complexity (25%).

Literature supports these observations by showing that the high cost of smart wearables hinders CKD patients from using smart wearables to manage their condition (Wieringa et al., 2017). The earlier studies on technology adoption have always indicated that users would not adopt technology that is perceived to be difficult to use (Davis, 1989; Rogers, 1995).

Sample t-test of Smart Wearable Usefulness

A one-sample t-test was conducted to determine whether the perceived usefulness of the smart wearable (coded as 1 = Yes, 2 = No) differed significantly from the midpoint of the scale (1.5). The results, which are displayed in Table 1.7 indicate that the mean usefulness score (M=1.16,SD=0.37) was significantly lower than 1.5, t(49) = =−6.49, p<.001, 95% CI [-0.45, -0.24].

This suggests that participants, on average, found the smart wearable to be useful for managing their condition, and hence confirming the findings reported in the previous sections.

Table1.7 One-Sample Test of Device Usefulness (Test Value = 1.5)

Variable	t	df	Sig. (2-tailed)	Mean Difference	95% CI Lower	95% CI Upper
Is the smart wearable useful to you in managing your condition?	-6.492	49	0.000	-0.3400	-0.445	-0.235

Logistic Regression of Smart Wearable Usefulness and Affordability

A logistic regression was conducted to determine if the affordability of a smartwatch predicted perceived usefulness of the device for managing CKD. The model was not statistically significant at the $\alpha = .05$ level (Wald $\chi^2(1) = 3.42$, $p = .064$). However, the odds ratio indicated that participants who could afford a smartwatch were 2.8 times more likely to find the device useful compared to those who could not afford it. These results are depicted in Table 1.8.

Table1.8 Logistic Regression Results

Variables	B	S.E.	Wald	df	Sig.	Exp(B)
Can you afford to purchase a smartwatch?	1.032	0.558	3.422	1	0.064	2.806
Constant	-3.569	1.194	8.943	1	0.003	0.028

One-Sample Test of Challenges of Smart Wearables in CKD Management

A one-sample t-test was conducted to determine whether the experience of challenges with the smart watch differed significantly from the midpoint of the scale (1.5). The results indicated that the mean challenge score (M = 1.51, SD = 0.51) was not significantly different from 1.5, t(48) = 0.14, p = .888, 95% CI [-0.14, 0.16]. These results, which are depicted in Table 1.9, suggest that the sample was evenly divided between those who experienced challenges and those who did not.

Table 1.9 One-Sample Test of Challenges of managing CKD through Wearable Devices

	Test Value = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Did you at any time have challenges using the smart watch	20.930	48	.000	1.5102	1.365	1.655

CONCLUSION

This study demonstrates the potential and feasibility of integrating smart wearables in the management of CKD. The findings of this study confirm the high patient adherence and engagement with the smart wearables in the management of CKD. These findings underscore the acceptability of this technology among the CKD patients who participated in this research. Although based on a small sample, these findings could be generalized not only to the CKD population but also to patients with other chronic diseases, which could benefit from the integration of smart wearables in their management. These findings revealed that the metric scores of patient activity and rest, which were captured via the smart wearable device, prove that the digitally captured behavioral and physiological trends are clinically relevant. More so, these findings have rejected the null hypothesis by proving that smart wearables are effective tools for managing CKD among both male and female, stage 3 and stage 4, and patients of various age groups. These observations were confirmed by such analyses as the t-test, logistic relations, and single variable and paired variable tests. However, our study was limited by the small sample size, which makes it difficult to generalize these findings across similar cases. Future studies could add more value by increasing the sample size and supplementing quantitative data with qualitative data that could reflect the lived experiences of CKD patients while using smart wearables.

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